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Urinary Potassium Is a Clinically Useful Test to Detect a Poor Quality Diet[1,2]

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Abstract

Poor eating habits, a strong predictor of health outcomes, are not objectively assessed in routine clinical practice. In this study, we evaluated the use of urinary potassium (K^+) as a means to identify people consuming a poor quality diet. Consecutive patients with kidney stones ($n = 220$), aged 18–50 y, from a population-based lithotripsy unit, collected a single 24-h urine sample to assess urinary K^+. They also completed a FFQ to derive the recommended foods score (RFS), an index of overall diet quality, and had their blood pressure, heart rate, weight, and height measured. Urinary K^+ was related positively with the intake of recommended food items, including vegetables, fruit, whole grains, low-fat dairy products, fish and poultry, and wine and negatively to those not recommended by current dietary guidelines, including red meat, fast food, and high-energy drinks. Urinary K^+ was also correlated with the RFS ($r = 0.226$; $P < 0.001$). Using a receiver operating characteristic curve, K^+ excretion values below the gender-specific median (men, 60 mmol/d; women, 41 mmol/d) were identified as the optimal cutoff values for a poor quality diet, indicated by the RFS. Higher urinary K^+ was inversely related to adjusted BMI (P-trend = 0.03), diastolic blood pressure (P-trend = 0.04) and heart rate (P-trend = 0.006), after controlling for potential confounders. Urinary K^+ provides a summary measure of diet quality, is significantly related to BMI, blood pressure, and heart rate, and may be useful clinically to detect poor dietary habits and monitor response to dietary interventions. J. Nutr. 139: 743–749, 2009.

Introduction

Poor eating habits are an important contributor to cardiovascular disease in developed countries. Prospective cohort studies of dietary patterns with mortality or morbidity as outcomes have demonstrated the beneficial effects of a healthy diet (1–3) and the benefits are additive with other lifestyle changes (3). Clinical trials have found substantial benefits of interventions that improve overall diet quality. Healthy diets reduce all-cause and cause-specific mortality in patients with coronary heart disease (4), lower blood pressure in both normotensive and hypertensive individuals (5,6), mitigate salt sensitivity in people who previously consumed a poor quality diet (7), and are associated with a lower BMI (8).

The Dietary Guidelines for Americans, 2005 provides authoritative advice about good eating habits, which include the consumption of a diet containing vegetables, fruit, whole grains, dairy products, fish and poultry, and wine (9). The principal aim of these guidelines is to promote health and reduce the risk of major chronic disease. However, surveys of dietary intake in the United States show that up to 80% of Americans are eating a diet that does not meet current recommendations (10,11) and, by extension, the problem of overweight and obesity is epidemic (12). Effectively identifying individuals at risk can help professionals to implement counseling strategies and improve food choices (13).

Present methods to assess dietary patterns rely on self-report instruments, such as FFQ, 24-h recall, or food records. Because these methods have significant limitations, biological markers of dietary intake are now being evaluated as an alternative (14). One potentially powerful biomarker is urinary potassium (K^+). It is a readily available, inexpensive biochemical test and is strongly related to dietary K^+ (15–17). K is a nutrient present in a wide array of foods, with the richest sources being leafy green vegetables, fruit from vines, and root vegetables, and a component of many foods and beverages that constitute a healthy eating pattern (1–3,5,7,9). In human feeding studies, participants randomly assigned to the Dietary Approaches to Stop Hypertension (DASH)[8] trial's combination diet had significantly higher urinary K^+ excretion than those consuming a typical American diet (5,7). The beneficial effects of the dietary intervention on blood pressure, the outcome of interest, occurred without a change in dietary sodium (Na^+) or body weight (5,7). Finally, a single 24-h urine K^+ measurement has been shown to be

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[8] Abbreviations used: DASH, Dietary Approaches to Stop Hypertension; RFS, recommended foods score; ROC, receiver operating characteristic.

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a significant predictor of coronary heart disease events and all-cause mortality (18).

The general objective of this study was to examine the use of urinary K^+ as a means to identify people consuming a poor quality diet. The specific objectives were to evaluate the relationship of urinary K^+ to different foods and food groups, to K^+ intake derived from a self-reported measure of diet, and to the recommended foods score (RFS), an index of overall diet quality (19). We also determined gender-specific optimum urinary K^+ threshold values that predict individuals consuming a poor quality diet, indicated by the RFS. These values were then related to BMI, blood pressure, and heart rate, clinical parameters associated with disease and chronic health problems. Finally, because the interaction of K^+ and Na^+ may have greater biological effects than absolute levels of intake (20), we evaluated urinary Na^+ and the Na^+:K^+ ratio as alternative indicators of overall diet quality and their association with clinical measures.

Methods

The study was conducted at the Kidney Stone Center in St. Michael's Hospital, which is a regional facility serving the needs of more than 6 million people living in the greater metropolitan area of Toronto. The hospital's Research Ethics Board approved the study. Between February 2002 and March 2004, consecutive patients, aged 18–50 y, with calcareous kidney stones who gave written informed consent provided salient personal and health information, completed a 166-item semi-quantitative FFQ validated for Canadian populations (21), and had their weight, height, and blood pressure measured in a standard manner. As part of their routine evaluation, patients collected a single 24-h urine specimen, starting the morning prior to their lithotripsy treatment. No specific dietary instructions were given and test results were not available at the time of participation.

Dietary assessment. The study staff reviewed the FFQ with each participant to discuss missed items and clarify ambiguities in recording. The FFQ measured the usual dietary pattern over the previous 12 mo to estimate nutrient and energy intake. Estimation of nutrients was based on the 2005 Canadian Nutrient File (22). Because there is no uniform definition of a poor quality diet, we used the results of a prospective cohort study in women that related RFS categories to health outcomes to select a threshold value (19). The RFS is the unweighted sum of the value of 1 given for each of 23 recommended food items that a person consumes at least once weekly and overall scores range from 0 to 23. The study demonstrated that a RFS value $\geq$ 9 was associated with a significant reduction in risk for both all-cause and cause-specific mortality. The value < 9 represents approximately the 35th percentile of the scores in women. For men, a comparable RFS score was <8. For the purpose of this study, we used these values to indicate a poor quality diet. The RFS scores were adjusted for age, gender, ethnicity, urinary creatinine, and energy intake.

Biochemical procedures. All 24-h urine collection bottles contained thymol crystals dissolved in isopropanol as a preservative. A single 24-h urine sample was collected and urinary measures were analyzed on commercially available analyzers (Beckman Synchron LX 20). Patients with a urinary creatinine value outside the daily reference range were excluded (8.8–22 mmol for men and 4.5–16 mmol for women) to eliminate patients with incomplete and inadequate collections (23). The laboratory CV at St. Michael's Hospital for the urinary K^+ measurement was 1.5%. The ratio of K^+:creatinine was derived as a secondary check for over- or under-collected urine samples with creatinine values within the acceptable range.

Statistical methods. Based on correlations reported in previous studies, which used biomarkers to validate diet quality measures (1), the power to detect a correlation of at least 0.20 was determined to be >80% with a sample size of 200, assuming a 2-sided test with $\alpha = 0.05$.

Patients were categorized into urinary groups, both by sex-specific distribution of 24-h urinary K^+ excretion and the urinary K^+:creatinine ratio. Means $\pm$ SD for continuous variables and percentages for categorical variables were computed for each urinary group. The urinary K^+ excretion of patients consuming a poor quality diet as derived from the RFS was compared with that of patients consuming an adequate diet. Urinary K^+ was then examined as the primary exposure variable (based on quartiles of excretion), whereas energy and food intake, which were approximately normally distributed within urinary groups, were the dependent variables. Covariates of interest included age, gender, ethnicity, urinary creatinine, and energy intake. ANCOVA was conducted, with tests for linear trend, to compare the mean values of intake among quartile groups of urinary K^+, while adjusting for the above covariates. The area under the receiver operating characteristic (ROC) curve was used to assess the discriminative ability of urinary K^+ as an indicator of poor diet quality. The results were used to classify individuals as low or normal K^+ excretors. The Hosmer and Lemeshow goodness-of-fit test was applied to assess model calibration (24). In selecting the optimal cutoff point, greater emphasis was placed on attaining a relatively higher sensitivity than specificity because of the potential harm associated with a poor quality diet. Patients identified as low K^+ excretors were compared with normal K^+ excretors on the intermediate health variables of BMI, blood pressure, and heart rate, adjusting for covariates. Similarly, men and women were compared on urinary K^+ normalized by urinary creatinine to account for gender-related differences in body mass. In secondary analyses, the urinary K^+:creatinine ratio was assessed as the primary predictor variable for dietary intake and the intermediate health variables and as the test variable in the ROC analysis. Because the results using the urinary K^+:creatinine ratio were virtually identical to those of the primary analysis, the paper focuses exclusively on urinary K^+ excretion. Lastly, ANCOVA was conducted, with tests for linear trend, to compare the mean values of intake and intermediate health variables among quartile groups of urinary Na^+ and the Na^+:K^+ ratio. Post hoc pairwise comparisons of means were made using Tukey's approach to adjust for multiple comparisons. All results, with the exception of the sociodemographic data, are reported based on multivariate analyses.

The analyses were conducted using SAS software version 8.1 (SAS Institute). *P*-values < 0.05 (2-tailed) were considered significant.

Results

Study population. Of 321 potentially eligible patients, 17 did not provide a 24-h urine collection and 19 had a 24-h urinary creatinine value outside the reference range. Of the remainder, 220 provided written informed consent and completed the FFQ. Participation rates were similar across urinary K^+ groups. There were no significant demographic or clinical differences between participants and nonparticipants. The final item nonresponse rate for the FFQ was 1.7% and did not vary by K^+ group.

The age of participants was 39.7 y and males and females were evenly represented (**Table 1**). Urinary K^+ excretion was 53.4 $\pm$ 22.2 mmol/d. The K^+:creatinine ratio was 4.1 $\pm$ 1.3 mmol/mmol and was higher in women (4.4 $\pm$ 1.4 mmol/mmol) than in men (3.9 $\pm$ 1.2 mmol/mmol; $P = 0.005$). The RFS score was 9.2 $\pm$ 4.0. The overall prevalence of comorbid conditions was <5% and none of the participants had cardiovascular disease or cancer.

Urinary K^+ and diet quality. The 24-h urinary K^+ measurement was positively correlated with usual intake of dietary K^+ over the past year, as derived from the FFQ ($r = 0.260$; $P < 0.001$). Energy intake and urinary K^+ were not associated ($r = -0.060$; $P = 0.38$) (**Table 2**). Urinary K^+ excretion was significantly and positively correlated with the intake of most recommended food items, including vegetables, fruit, whole grains, low-fat dairy products, fish and poultry, and wine and negatively with those

TABLE 1 Characteristics of participants overall and by urinary K group[1]

	All	Low K	Normal K	*P*-value
n	220	109	111	
Age, *y*	39.7 ± 7.7	37.8 ± 8.4	41.6 ± 6.4	<0.001
Male gender	114 (51.8)	58 (53.2)	56 (50.5)	0.88
Caucasian	179 (81.4)	88 (80.7)	91 (82.0)	0.98
Currently married	154 (70.0)	69 (63.3)	85 (76.6)	0.08
≤High school education	62 (28.2)	29 (26.7)	33 (29.8)	0.65
Household income<$40,000	64 (32.4)	38 (37.6)	26 (27.1)	0.11
Current smoker	51 (23.3)	25 (23.3)	26 (23.4)	0.99
Multivitamin use	63 (28.6)	30 (27.6)	33 (29.8)	0.48
Recurrent kidney stone	128 (58.5)	63 (58.3)	65 (58.6)	0.88

[1] Values are means ± SD or *n* (%).

generally not recommended, including red meat, fast food, and high-energy drinks (Table 2).

Urinary K^+ excretion was positively correlated with RFS derived diet quality scores ($r = 0.226$; $P < 0.001$). Participants with a low RFS had a lower 24-h urinary K^+ than those with a normal score (48.2 ± 19.1 mmol/d vs. 56.1 ± 22.9 mmol/d; $P = 0.009$).

ROC curves for urinary K^+ and diet quality. From the ROC curve analysis (**Fig. 1**), the 50th percentile of the 24-h urinary K^+ excretions provided a high sensitivity (0.87; 95% CI: 0.76–0.94) and acceptable specificity (0.61; 95% CI: 0.53–0.68) for a poor diet quality. The corresponding urinary threshold values were 60 mmol/d in men and 41 mmol/d in women. The area under the ROC curve for urinary K^+ was 0.76 (95% CI: 0.64–0.88; $P < 0.001$) and there was good calibration as indicated by the Hosmer and Lemeshow goodness-of-fit test ($P = 0.49$, nonsignificant). Participants with higher K^+ levels were more likely to be older ($P < 0.001$) and tended to be married ($P = 0.08$) and to have a greater household income ($P = 0.11$) (Table 1).

Urinary K^+ and intermediate outcome variables. Urinary K^+ excretion was inversely correlated with BMI ($r = -0.149$; $P < 0.05$), heart rate ($r = -0.195$; $P < 0.01$), and diastolic blood pressure ($r = -0.139$; $P < 0.05$). We found similar results when the data were analyzed by quartiles (**Table 3**) or as a binary variable (low vs. normal excretors) (**Table 4**).

Urinary Na^+ and Na^+/K^+. Urinary Na^+ and the Na^+:K^+ ratio were not significantly correlated with the intake of recommended foods or with items that are not generally recommended. They were also not associated with the RFS-derived diet quality

TABLE 2 Intake of selected foods or food groups by quartile of K excretion[1]

	Quartile 1	Quartile 2	Quartile 3	Quartile 4	*P*-trend	Pearson correlation Coefficient[2]
Median urinary K, *mmol/d*	29	48	54	81		
n	55	54	55	56		
Energy intake, *kJ/d*	8989 ± 4078	8399 ± 3940	8558 ± 2901	8315 ± 2989	0.46	−0.060
Vegetables (total), *g/d*	217.1 ± 202.4	190.4 ± 127.2	257.8 ± 174.6	293.9 ± 202.4	0.02	0.141*
Dark-yellow, *g/d*	16.3 ± 23.7	16.8 ± 20.5	30.5 ± 42.8	36.2 ± 52.0	<0.001	0.175**
Green-leafy, *g/d*	23.4 ± 22.1	25.1 ± 28.2	32.3 ± 27.7	36.8 ± 33.6	0.02	0.129*
Cruciferous, *g/d*	33.0 ± 32.9	26.1 ± 29.1	41.4 ± 48.9	44.5 ± 44.0	0.08	0.156*
Tomatoes, *g/d*	41.2 ± 55.3	38.6 ± 35.7	39.3 ± 39.1	58.3 ± 57.5	0.14	0.122
Legumes, *g/d*	22.0 ± 38.8	21.3 ± 21.3	28.7 ± 36.3	28.4 ± 28.2	0.24	0.057
Other, *g/d*	57.5 ± 66.5	48.2 ± 44.5	65.6 ± 78.7	72.1 ± 63.3	0.18	0.076
Fruits, *g/d*	153.9 ± 167.8	155.1 ± 120.2	196.1 ± 170.6	272.1 ± 163.5	<0.001	0.255***
Whole grains, *g/d*	28.8 ± 44.8	34.8 ± 38.7	38.8 ± 43.6	48.2 ± 45.5	0.046	0.182**
Refined grains, *g/d*	102.9 ± 74.8	130.0 ± 152.5	107.1 ± 97.5	118.6 ± 101.7	0.72	0.016
Fish and poultry, *g/d*	39.3 ± 41.5	48.1 ± 47.1	58.8 ± 57.0	58.9 ± 49.4	0.046	0.185**
Low-fat dairy, *g/d*	106.5 ± 183.6	87.6 ± 161.1	120.4 ± 212.0	241.0 ± 336.2	0.008	0.211**
Regular-fat dairy, *g/d*	176.3 ± 294.2	222.5 ± 349.2	195.4 ± 168.5	193.3 ± 173.5	0.89	0.019
Nuts, *g/d*	3.10 ± 9.9	2.76 ± 5.0	10.30 ± 18.3	9.85 ± 21.4	0.01	0.107
Wine, *g/d*	12.4 ± 32.8	14.8 ± 33.3	25.8 ± 42.8	29.9 ± 46.2	0.03	0.166*
Red meat, *g/d*	76.1 ± 70.8	54.3 ± 41.7	56.0 ± 50.7	44.7 ± 47.5	0.01	−0.135*
Processed meat, *g/d*	6.74 ± 11.5	4.49 ± 4.1	4.20 ± 3.9	4.79 ± 5.6	0.20	−0.064
Sweets and desserts, *g/d*	70.5 ± 68.3	71.3 ± 61.1	62.5 ± 48.0	62.4 ± 58.4	0.36	−0.066
High-energy drinks, *g/d*	353.5 ± 608.2	162.0 ± 191.4	156.7 ± 240.4	42.9 ± 138.0	<0.001	−0.245***
Fast food, *g/d*	83.7 ± 72.3	81.0 ± 90.5	62.7 ± 51.5	58.7 ± 57.8	0.04	−0.167*

[1] Values are means ± SD adjusted for age, gender, ethnicity, energy intake, and urinary creatinine excretion. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
[2] Correlation of urinary K^+ excretion with each dietary variable while controlling for age, gender, ethnicity, energy intake, and urinary creatinine excretion using linear regression.

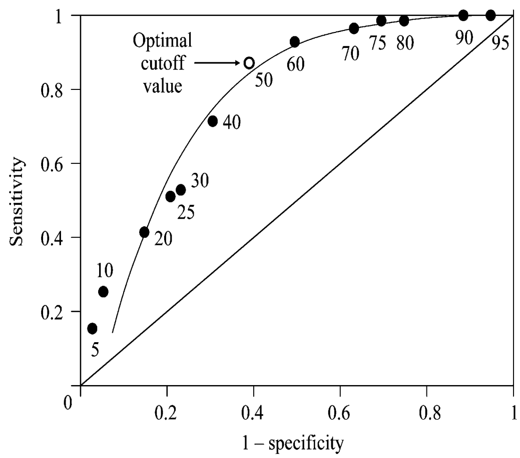

FIGURE 1 ROC curve for urinary K excretion in the assessment of a poor-quality diet. Black dots represent normality cutoff points for 24-h urinary K in percentiles. White dot represents the optimal cutoff point. The K excretion cutoff points, in mmol/d, for men and women, respectively, at each percentile value (given in parentheses) are: 30 and 19 (5th), 36 and 23 (10th), 41 and 29 (20th), 45 and 31 (25th), 49 and 31 (30th), 55 and 35 (40th), 60 and 41 (50th), 67 and 45 (60th), 74 and 51 (70th), 77 and 55 (75th), 81 and 60 (80th), 90 and 68 (90th), and 106 and 77 (95th).

scores (Na^+: $r = 0.058$, $P = 0.392$; Na^+:K^+: $r = -0.036$, $P = 0.595$) or any clinical measures.

Discussion

In this study, we examined the use of urinary K^+ as a clinical measure of overall diet quality. It was based on the premise that healthy dietary patterns typically include foods that are good sources of dietary K^+ (1–5). We found that increased urinary K^+ excretion was associated with a higher intake of foods that are recommended in dietary guidelines, including vegetables, fruit, whole grains, low-fat dairy products, fish and poultry, and wine (9), and a lower excretion was correlated with foods not considered part of a prudent eating pattern, including red meat, fast food, and high-energy drinks (25). The urinary K^+ measurement was correlated to the RFS, a global measure of diet quality, which has been shown to be a predictor of both all-cause and cause-specific mortality in the general population (1,19). Low urinary K^+ excretors in our study had a urinary K^+ excretion of 40.7 mmol/d, a level virtually identical to that of participants in feeding studies purposely given the control or typical American diet (5,7). Urinary K^+ was also correlated with several intermediate health variables (BMI, heart rate, and blood pressure), which are linked to health outcomes. Lastly, this study extends the use of nutritional biomarkers by showing that it may be used as a diagnostic test of overall diet quality.

Indices of overall diet quality have traditionally relied on self-reported assessment instruments to gather dietary information. These tools have several shortcomings, including the difficulties patients encounter to complete them, the need for trained staff to review the information collected, and the requirement for an up-to-date nutrient database for analysis. Furthermore, some respondents, especially those who are overweight or underweight, do not accurately report their actual food intake (26,27). In addition, energy intake assessed by self-report is often positively correlated with diet quality scores (19), which may be a source of bias. In our study, the RFS, consistent with past reports, was correlated with energy intake ($r = 0.389$; $P < 0.001$). In contrast, our urinary K^+ measurements were not associated with total usual energy intake. Thus, associations were not confounded by energy intake.

Nutritional biomarkers are considered to be a more objective measure of dietary intake (14,26). Most biomarkers used to assess diet quality are measured as concentration values and thus do not provide an estimate of absolute intake. Urinary K^+, measured as excretion over a time period, addresses this limitation (14). Although there have been no formal validation studies of urinary K^+ as a measure of overall diet quality, the DASH trials, which are human feeding studies involving random allocation of participants to diets of different nutritional value, provide credence that improved diet quality is related to urinary K^+ excretion (5,7). Thus, urinary K^+ appears to offer a clinically useful way to monitor dietary patterns.

The adverse health effects of a poor quality diet have been amply demonstrated in intervention trials (4) and prospective cohort studies, using cardiovascular disease and cancer mortality as outcomes (1–3). From studies examining the health effects of single nutrients, it is estimated that more than one-half of North Americans consume less than the recommended amounts of a wide array of nutrients in their diet, including K^+ (recommended intake, 4.7 g/d or 120 mmol/d) (28) and foods that are good sources of K^+ (28,29). Studies using indices of overall diet quality also indicate that a large segment of the American population eats a diet judged to be poor, fair, or needing improvement (10,11). Recent evidence indicates that there is no overall improvement in the past decade and, disturbingly, the consumption of fruit and vegetables has fallen significantly (11,29,30).

Poor dietary habits have been implicated in the present obesity epidemic in North America. Many studies have demonstrated that increased consumption of fast food and high-energy drinks, hallmarks of a Western dietary pattern, predicts the

TABLE 3 The relationship of intermediate health variables to urinary K quartiles[1]

	Quartile 1	Quartile 2	Quartile 3	Quartile 4	*P*-trend
Median urinary K, *mmol/d*	29	48	54	81	
n	55	54	55	56	
BMI, *kg/m²*	28.7 ± 6.5	28.1 ± 5.9	26.6 ± 4.9	26.5 ± 4.8*	0.03
Systolic BP,[2] *mm Hg*	123.9 ± 15.6	124.1 ± 20.1	125.3 ± 19.9	119.0 ± 14.0	0.27
Diastolic BP, *mm Hg*	77.3 ± 11.5	75.8 ± 13.4	76.3 ± 13.5	71.4 ± 9.0*	0.04
Heart rate, *beats/min*	80.2 ± 11.6	76.6 ± 14.5	76.4 ± 12.6	71.4 ± 11.1*	0.006

[1] Values are means ± SD adjusted for age, gender, ethnicity, education, energy intake, and urinary creatinine excretion. *Different from quartile 1, $P < 0.05$.
[2] BP, Blood pressure.

TABLE 4 Intermediate health variables by urinary K group[1]

	Low	Normal	*P*-value
n	109	111	
BMI,[2] *kg/m²*	28.4 ± 6.2	26.5 ± 4.8	0.01
Systolic BP,[3] *mm Hg*	124.0 ± 17.8	122.1 ± 16.9	0.42
Diastolic BP,[3] *mm Hg*	76.6 ± 12.5	73.8 ± 11.3	0.08
Heart rate,[3] *beats/min*	78.4 ± 13.1	73.9 ± 11.8	0.008

[1] Values are means ± SD.
[2] Adjusted for age, gender, ethnicity, education, energy intake, and urinary creatinine excretion.
[3] Adjusted for age, gender, ethnicity, BMI, education, energy intake, and urinary creatinine excretion. BP, Blood pressure.

development of weight gain, insulin resistance, and metabolic syndrome (31–33). Although fast food items such as French fries and pizza sauce and high-energy beverages may contain K^+, there is evidence that consumers of these products overall have a lower intake of recommended foods that are considered to be good sources of K^+ (31,32). This may account for our findings of an inverse association of urinary K^+ and fast food intake and the negative correlation with high-energy drinks.

Urinary K^+ itself is related to health risk. In a large population-based cohort study, both men and women in the lowest quintile of urinary K^+ excretion had a significantly higher incidence of coronary heart disease events and death from all causes (18). A low-K^+ diet induces salt sensitivity (34), which is associated with an increased risk of mortality (35). In experimental studies, normotensive individuals given a low-K^+ diet had increased blood pressure that returned to normal upon K^+ repletion (36). The DASH trials showed that a high-quality diet increases urinary K^+ excretion and reduces blood pressure (5,7). In keeping with these findings, we observed an inverse relationship between K^+ intake and diastolic blood pressure. We also found an independent, negative correlation between urinary K^+ and BMI. Our BMI findings are consistent with NHANES data, which showed a significant decrement in BMI with increasing dietary K^+ intake (37). It is also congruent with new clinical trial data showing greater weight loss in women consuming a diet that promotes increased vegetable and fruit intake, good sources of dietary K^+ (8).

The inverse association in this study between resting heart rate and K^+ excretion is a novel observation. Increased heart rate is strongly associated with hypertension independently of other risk factors. Falkner et al. (38) showed that normotensive offspring of hypertensive patients exhibit marked increases in heart rate and plasma catecholamine levels in response to mental stress. In the Framingham Heart Study, heart rate was a strong clinical predictor of incident hypertension in both genders (39). More importantly, an elevated heart rate has been shown in several epidemiologic studies to be strongly predictive of subsequent cardiovascular events (40–42). The mechanism behind the inverse association of resting heart rate with K^+ excretion is not known but might be related to a lower BMI and dampening of sympathetic nerve activity (43) or reducing plasma leptin concentrations (44).

Our finding that women reported consuming a higher-quality diet than men is consistent with previous observations (10,45) and congruent with higher urinary K^+:creatinine ratio in women compared with that in men. These gender differences suggest that women are more knowledgeable regarding healthy food choices and make better food selections or are more involved in food preparation, particularly in the context of the family environment.

In our study, dietary K^+ derived from the FFQ was positively correlated with urinary K^+ excretion. Other studies where the estimate of dietary K^+ intake (calculated from food diaries or dietary recall methods or direct analysis of duplicate diets) was determined during or in close proximity to the 24-h urine collections (1–6 wk) found even stronger correlations, ranging from 0.58 to 0.92 (5,15–17,46). The smaller correlation between urinary and dietary K^+ measures in our study likely reflects the longer time horizon of the FFQ, which was 1 y. It is also possible that there was greater measurement error with the FFQ than the other self-reported measures of dietary intake, which attenuated the correlation. Nonetheless, it would appear that regardless of the method used to collect data on dietary habits, urinary K^+ does reflect the usual dietary intake of K^+.

We found that Na^+ and the Na^+:K^+ ratio were not associated with overall diet quality or the clinical measures. These findings are consistent with evidence from the DASH trials showing that healthier food choices lowered blood pressure without restricting dietary salt intake (5,7). It could also reflect that the estimates of reliability for 24-h urinary Na^+ and Na^+:K^+ are poorer than those for 24-h urinary K^+ (47).

Our study has several important strengths. The Kidney Stone Center serves a broad segment of the community and the study participants may reasonably be considered a population-based cohort. Study participants were recruited consecutively and were not provided with any specific dietary advice before all evaluations were completed, including the dietary assessment. The similar proportion of patients with recurrent kidney stones across the urinary K^+ groups suggests that any possible prior dietary instructions to prevent stone recurrences had no lasting impact on dietary choices. Apart from having kidney stones, virtually none of the participants had comorbid diseases; thus, they were unlikely to have changed their dietary habits to maintain good health. The dietary assessment was conducted before the results of the urine tests were known. Finally, the median RFS value of 10 in women corresponded closely to the median of 11 in the study of Kant et al. (19), who derived the RFS.

The study also has some limitations. Because study participants were only calcareous stone-formers, these findings will need to be evaluated in other populations to assess the generalizability. The threshold values for the urinary parameters were derived from a single 24-h urine collection. Because of day-to-day within-person variability of K^+ intake, multiple measurements are recommended to estimate usual dietary intake (16,48). In one study, 8 d of urinary collections and 16 d of dietary records provided estimates, which were almost as high as 30-d samples (16). However, multiple urine collections are not practical in usual clinical practice and would reduce the relevance of the test for health care providers. Lastly, normalizing urinary K^+ values by creatinine produced virtually the same associations and ROC results, suggesting that the potential improper collection of 24-h urine specimens is unlikely to have been a factor in this study.

In summary, increased urinary K^+ was associated with a healthier diet quality score, better adherence to current dietary recommendations, and a lower BMI, diastolic blood pressure, and heart rate. A urinary K^+ excretion value < 60 mmol/d in men and 41 mmol/d in women indicated the consumption of a poor-quality diet. We suggest that a single 24-h urinary K^+ measure is a clinically valid, simple, and inexpensive ($10.00 in Canada) test of overall diet quality, which may aid physicians in providing effective dietary counseling to patients at greatest risk

because of poor food choices and in monitoring the response to dietary interventions.

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